JS Army Corps
of Engineers
North Central Division

GREAT LAKES LEVELS

Update Letter No. 84 July 2, 1992

Great Lakes Flow Metering

Have you ever wondered how much water flows out of one of the Great Lakes? Does the amount of flow change from day to day? This article is intended to explain how flows are measured and how this information is used.

An important part of the data collection program in the Great Lakes system is the measurement of flows in the connecting channels, which include the St. Marys, St. Clair, Detroit, and Niagara Rivers and their diversions, and the upper reach of the St. Lawrence River. The U.S. Army Corps of Engineers, Detroit District (successor to the former Corps' U.S. Lake Survey), and Environment Canada, Water Survey of Canada, Ontario Region, are the United States and Canadian agencies presently responsible for discharge measurements on the connecting channels.

The first recorded discharge measurements in the connecting channels were taken in the St. Clair River in 1867 by the U.S. Lake Survey. Since then, thousands of measurements have been gathered in these channels for various purposes, by both public and private organizations in both countries. However, only those measurements taken by federal agencies fall within the scope of this Update Letter.

Why Measure?

The main purpose of discharge measurements in the connecting channels is to collect flow data for the development of ratings of water level gauges and control structures. (By rating we mean the development of a table or equation that relates water levels at a gage to flow past a particular location. Usually one gage is used, but sometimes two gages are used.) Figure 1 shows a Corps' survey vessel in the process of conducting a measurement. Data are also collected for a number of other applications, including input to mathematical (numerical) and physical hydraulic models, calibration of velocity meters, and flow distribution studies. Several numerical models are in use for predicting lake levels and flows in the connecting channels. Several

Figure 1. Corps' Survey Vessel Conducting Flow Measurement

physical models of the Niagara and St. Lawrence Rivers have also been built by the Corps of Engineers at its facility in Vicksburg, Mississippi, and by Ontario Hydro in Toronto, Ontario, Canada. Discharge data are used operationally in navigation, power production, and lake regulation; for water apportionment and monitoring compliance with agreements and treaties, and in a wide variety of studies.

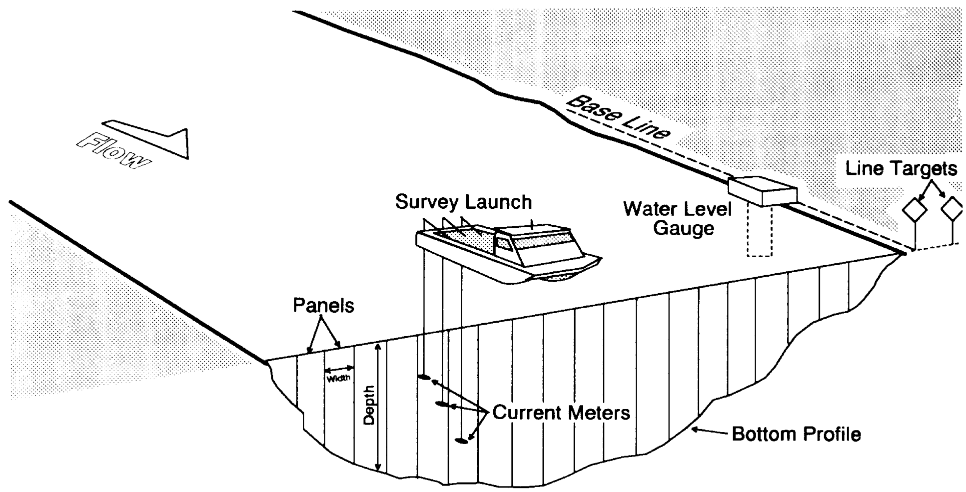

Figure 2. Sketch of a Channel Cross Section

Measurement Methodology

The discharge of a stream at a measurement section is usually defined as the volume of water in cubic meters, or cubic feet, flowing past a particular point on the stream in a unit period of time, usually one second. This leads to the most commonly used units of measure in hydraulics, cubic meters per second (cms) and cubic feet per second (cfs).

The velocity-area method is the prime method of discharge measurement on the connecting channels and the main subject of this article. It involves subdivision of a measurement section into an appropriate number of segments, called panels, as illustrated in Figure 2. There are usually ten to twenty-five panels, depending on the width of the channel.

This method is based on the relationship Q = VA, or discharge (Q) is the product of corresponding values of mean panel velocity (V) and cross-sectional panel area (A).

The panel area (A) is the product of the panel width and the average depth of the water in the panel, as determined during the measurement. The mean panel velocity (V) is computed from measured velocities at each one-tenth of the depth measured at the center of each panel (based on current meters). Because the flow velocity varies with depth, it is measured at a number of points to determine the mean velocity. (The velocity is slowest near the surface and bottom and usually greatest at about three-tenths of the total depth.) Panel discharge is then computed as the product of the mean velocity and panel area, and the total discharge at the measurement section is the sum of all the individual panel discharges.

The two major types of velocity-area measurement methodologies presently being practiced on the connecting channels are: conventional metering measurements, in which the boat is held stationary while current velocity is measured at selected points across the section; and moving-boat measurements, in which the current velocities are continuously measured at a fixed water depth while the boat is crossing the section. Conventional measurements, or stationary platform measurements, date back to the start of the measurement program on the Great Lakes and account for the majority of the historic measurements. The moving-boat technique was developed in the 1950s, and introduced in the connecting channels in the 1960s. This technique has since gained general acceptance, and its use is increasing because measurements can be taken faster and require less labor and equipment as compared to conventional measurements.

Another type of velocity measurement system, presently more suited to continuous than discrete measurement, is the acoustic velocity meter (using sound waves). This methodology was developed in the 1950s and is based on the principle that an acoustic (sound wave) signal travelling in a moving medium travels faster with the current than against it, by an amount proportional to the current speed. It is slowly gaining acceptance despite some practical difficulties in meter installation and the adverse effects that ice, sediment and debris have on the readings.

Floats and chemical tracers ~n also be used to measure the velocity component in velocity-area discharge measurements, but there are few such measurements on record in the connecting channels. These have been mainly for flow distribution and direction surveys, as well as time of travel studies.

Direction of flow surveys, consisting of tracing the paths of floats or drogues over a specified length of the river, may also be conducted. The path of the float as it drifts with the current is tracked by at least two, and preferable three, surveying instruments (theodolites or transits) stationed at strategic points on the river banks. Before automated plotting became common in the early to mid 1970s, rection of flow surveys were plotted manually at the site, either in a hotel room or an office trailer, in the evening following a day's field measurements. Today, however, the usual practice is to return the data to the office for computer processing and plotting.

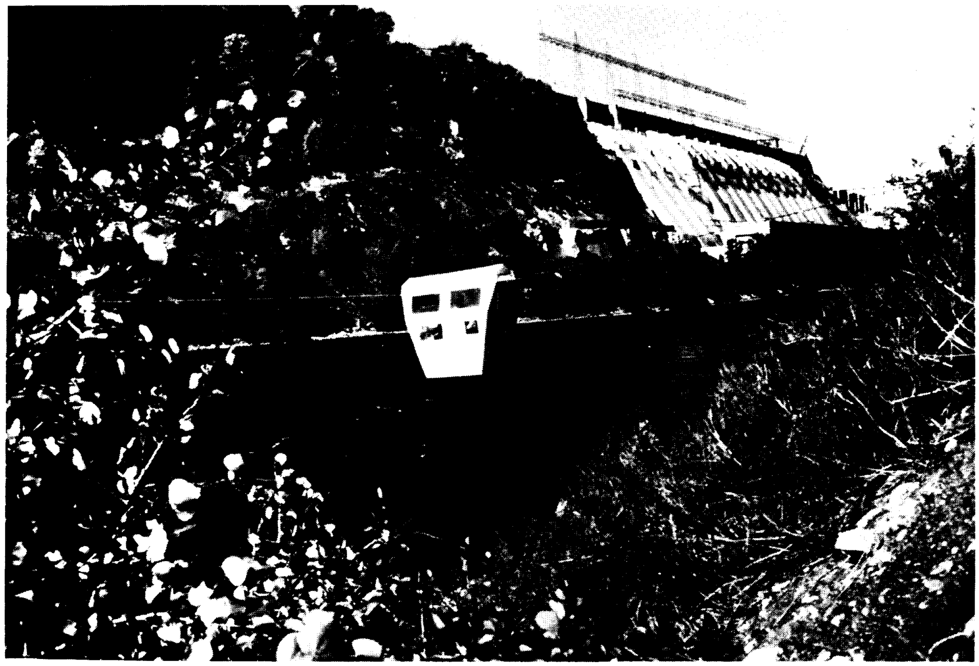

Figure 3. Discharge Measurement Using a Suspended Cable on the Niagara River

Measurement Platforms

Catamarans, or twin hulled vessels, were the measuring platforms usually associated with discharge measurements on the connecting channels, until the early 1970s. Developed over the years, specifically for this type of service, the catamaran features included shallow draft, low current resistance, and a maximum sable deck area in close proximity to the water surface.

Other types of boats, such as motor launches, have now replaced catamarans on the connecting channels because of their greater versatility and mobility. Additional fixed platforms, such as bridges, cableways, and thick ice covers, are also used for taking measurements.

Due to navigational above-water clearance requirements of 120 feet, the fixed bridges over the shipping lanes of the connecting channels are usually too high to serve as satisfactory measuring platforms for discharge measurements. For this reason, most bridge measurements have been confined to the non-navigable channels in the system.

The only permanent suspended discharge-measuring cable in the Great Lakes system is the Robert Moses Cableway, which spans the gorge in the lower Niagara River about 330 feet upstream from the New York State Power Authority's Robert Moses Generating Station (Figure 3). Its cablecar is constructed of aluminum panels on a steel frame. It carries two people and a meter is driven by a small motor. A meter is lowered through the side of the car to obtain current velocities.

Discharge measurements through an ice cover have only been taken on the connecting channels in the St. Marys and St. Lawrence Rivers. A specially designed ice sled is used to transport and support the metering equipment. The meter is lowered through a two-foot by three-foot hole cut in the ice at each measuring panel.

Standards

The first recorded international cooperative discharge measurement program in the Great Lakes system was on the St. Lawrence River at the Point Three Points Section (just downstream of the

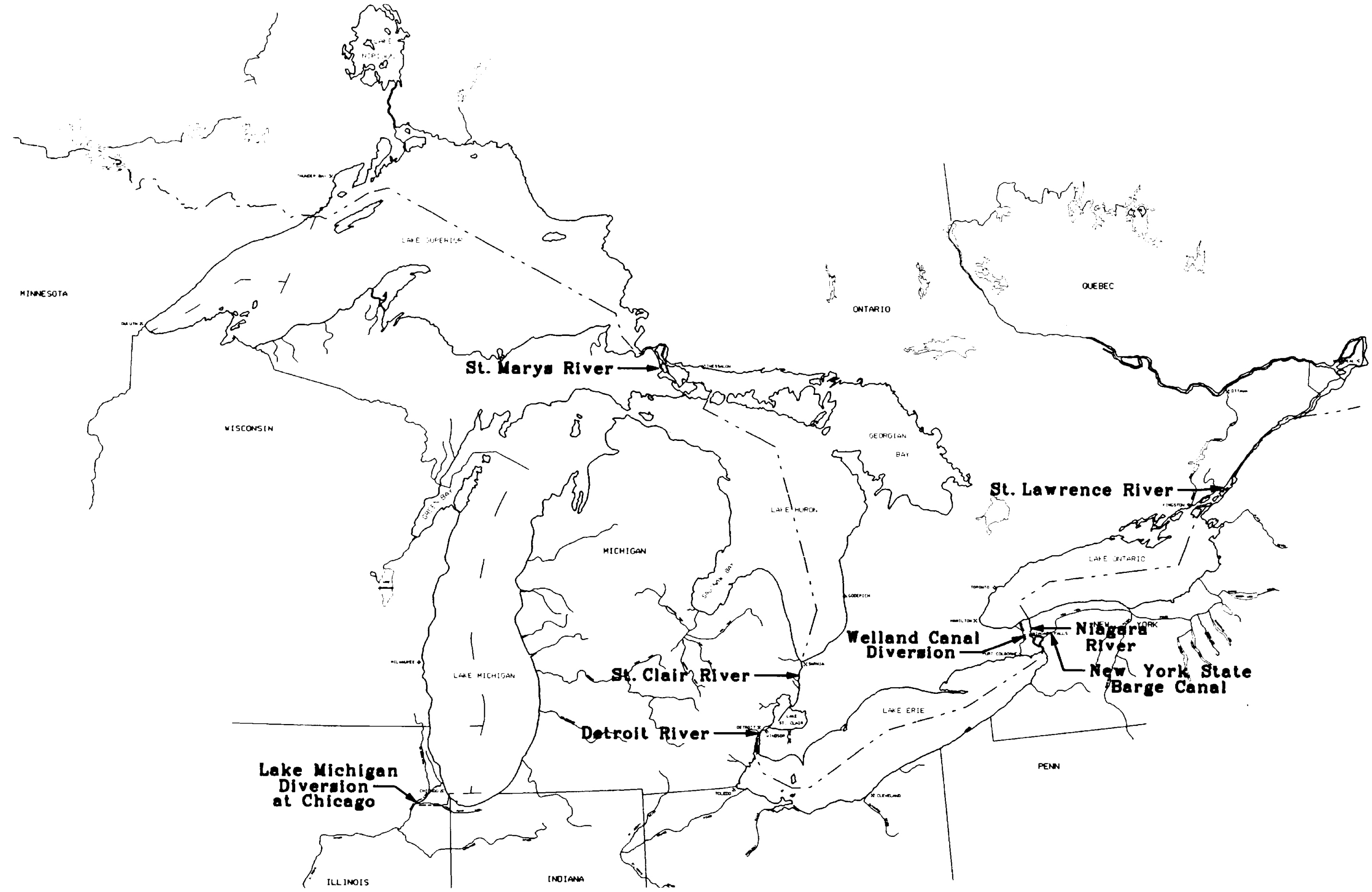

Figure 4. Locations of Measurement Sites in the Great Lakes

present Iroquois Lock) in 1953. The program used conventional methodology and was part of the St. Lawrence Seaway and Power Project. It also coincided with the formation of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. Until then, U.S. and Canadian agencies had operated independently, with an occasional exchange of observers, and each had developed its own general procedures and standards.

The present set of standards of the Corps of Engineers and the Water Survey of Canada for first order (greatest accuracy) conventional discharge measurements on the connecting channels was introduced in 1972. These standards specify a minimum of twenty panels in any section with not more than ten percent of the total area of discharge represented by any one panel.

These standards were accepted by the International Niagara Working Committee in 1973, which that year initiated measurements at the newly erected Robert Moses Cableway and at the International Railway Bridge section of the upper Niagara River.

The accuracy of measurements conducted in accordance with these standards can be expected to average about five percent. That is, the total measured flow is expected to be less than five percent different from the "true" flow. This assumes average hydraulic conditions at the measuring sections and reasonably steady flows. When less accuracy is required, such as for approximate flow distributions, discharges affected by ice, or other variable conditions, the standards are downgraded to save time and resources.

The performance standards of moving boat measurements are primarily related to the number of measuring points in a section, the maximum departure from the section line during traverses, and the determination of coefficients (relating average flow velocity to the velocity measured at two depths). Accuracy of this methodology is usually within about five percent of the conventional methodology.

Measurement Sites

Many of the be measurement sites were identified and established early in the Great Lakes program by the U.S. Lake Survey and remain in place to the present time. Good measurement sites are where the flow is parallel across the measuring section (i.e., doesn't change direction), the bottom profile is relatively smooth and stable through time, and is close to the water level gage or flow control site.

Some of the original sites include: Brush Point, Bridge, Sprys Dock, Brewery, Gates, West Neebish, and Middle Neebish Sections on the St. Marys River; Drydock, St. Clair, Roberts Landing, and Bay Point Sections on the St. Clair River; Fort Wayne Section on the Detroit River; International Railway Bridge, Black Rock, and Austin Street Sections on the Niagara River; and Point Three Points, Iroquois Point, Leishman Point, Weaver Point, and Massena Point Sections on the St. Lawrence River.

Other recently established sites include the following: Upper Gate and Lower Rapids Sections on the St. Marys River, established for measurement of discharge of the Lake Superior Compensating Works; Chippawa and Tonawanda Sections of the Upper Niagara River, for the measurement of flow distribution around Grand Island; American Falls Section, for the measurement of discharge over the American Falls; and the Robert Moses Cableway Section, also on the lower Niagara River, for the measurement of Maid-of-the-Mist-Pool outflows for verification of the flow over Niagara Falls. Figure 4 shows the locations of the measuring sections.

Next month we will continue this topic. The mechanics of selecting sites, establishing controls, taking soundings, and the process of measuring flows will be discussed.

Levels Reference Study

Three Progress Review Meetings were held in May 1992. The first addressed the issue of natural resources and was held in Baraga, Michigan. About 30 people participated in round table discussions.

The second Progress Review Meeting was held in Toledo, Ohio, to discuss the measures for evaluation. These include lake regulation, land use and management practices, and crisis conditions responses. About 30 non-study participants attended.

The third Progress Review Meeting dealt with erosion processes and potential damages, and was held in Burlington, Ontario. About 50 members of the public attended and engaged in lively discussion, primarily on the erosion processes work.

A Progress Review Meeting was held in June at Burlington, Ontario, to address electric power, commercial navigation, and recreational boating aspects of the study.

Public Forums will be held this November and December to discuss the study's draft findings and conclusions. Further details will be provided later on these meetings.

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Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 1. Precipitation data include the provisional values for the past month and the year-to-date and long-term averages. The provisional and long-term average water supplies and outflows are also shown.

Table 1
Great Lakes Hydrology[1]

PRECIPITATION								
BASIN	JUNE				YEAR-TO-DATE			
	1992*	AVG.**	DIFF.	% OF AVG.	1992*	AVG.**	DIFF.	% OF AVG.
Superior	2.2	3.3	-1.1	67	11.9	13.1	-1.2	91
Michigan-Huron	1.8	3.1	-1.3	58	11.8	14.6	-2.8	81
Erie	2.4	3.4	-1.0	71	16.0	17.1	-1.1	94
Ontario	2.0	3.1	-1.1	65	16.9	16.7	0.2	101
Great Lakes	2.0	3.2	-1.2	62	13.0	14.8	-1.8	88

LAKE	JUNE WATER SUPPLIES***		JUNE OUTFLOW[3]	
	1992[2]	AVG.[4]	1992[2]	AVG.[4]
Superior	78,000	158,000	83,000	78,000
Michigan-Huron	101,000	204,000	186,000[5]	193,000
Erie	13,000	30,000	208,000[5]	214,000
Ontario	27,000	42,000	272,000	261,000

***Estimated (inches) **1900-90 Average (inches)**
*****Negative water supply denotes evaporation from lake exceeded runoff from local basin.**

[1]Values (excluding averages) are based on preliminary computations.
[2]Cubic Feet Per Second (cfs) [3]Does not include diversions [4]1900-89 Average (cfs)
[5]Reflects effects of ice/weed retardation in the connecting channels.

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